HiLumi

LARGE HADRON COLLIDER

Research supported by the High Luminosity LHC project

HiLumi LHC: Correction of D2

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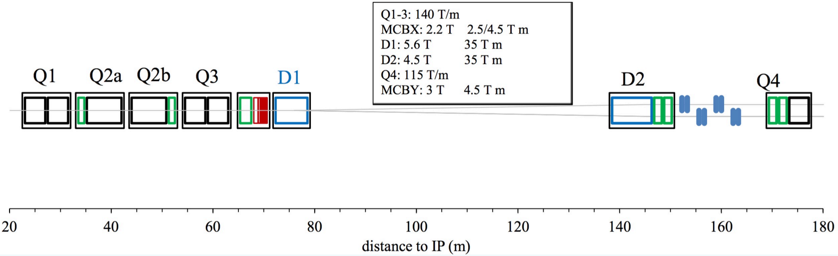
Outline

Aim

- We want to use the non-linear correctors to correct the field quality of D2 (MBRD)
- This is an extension of the current correction algorithm
- Not trivial: D2 has two apertures, correctors have one

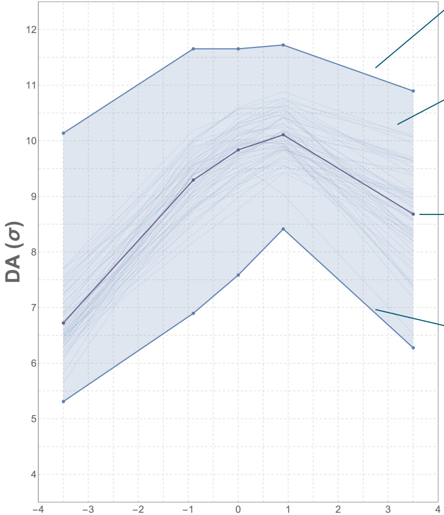
  $\Rightarrow$ Correction of both beams simultaneously !



Setup

- DA is calculated over:
  - 5 angles (15°, 30°, 45°, 60°, and 75°)
  - 60 random realisations (‘seeds’)
- Unless otherwise noted, all errors assigned at nominal value
- HLLHC 1.0 optics

Example DA plot



absolute maximum
(maximum angle over all seeds)

individual seed lines
(average over angles per seed)

average DA
(average over angles and over seeds)

absolute minimum
(minimum angle over all seeds)

Approach

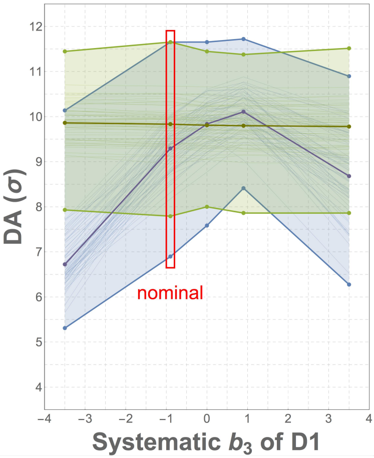
- Best we can do, is to correct the average of the errors of both apertures in D2
- Systematic errors in D2 are antisymmetric for even and symmetric for odd orders, and skew error components have no systematic part
  - $\Rightarrow$ Systematic errors: only b_3 and b_5 can be corrected
  - $\Rightarrow$ Random error parts can be corrected at all orders (up to b_6), but physical reproductivity should be taken with a grain of salt
- Closest single-aperture magnet is D1
  - $\Rightarrow$ use it to compare efficiency of correction algorithm

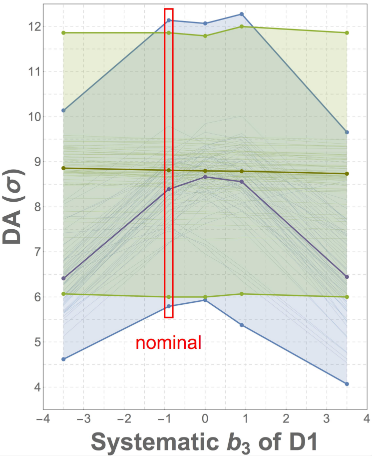
Outline

DA in function of b_3 of D1

$E = 7000$ GeV
$\varepsilon_n = 3.75\ \mu$m
$\beta_1^* = 0.15$ m
$\beta_2^* = 10$ m
$\beta_5^* = 0.15$ m
$\beta_8^* = 3$ m
$\theta_c^{1,5} = 590$ mrad
$d_{sep}^{1,5} = 4$ mm
$Q_x = 62.31$
$Q_y = 60.32$
$Q' = 3$
$I_{\mathrm{MO}} = 0$ A
$\mu_x^{1\to5} = 31.210$
$\mu_y^{1\to5} = 30.373$
$\phi_1 = 90°$
$\phi_5 = 0°$

Beam 1 (no errors in D2) **Beam 4**





— no correction
— full correction

DA in function of b_3 of D2

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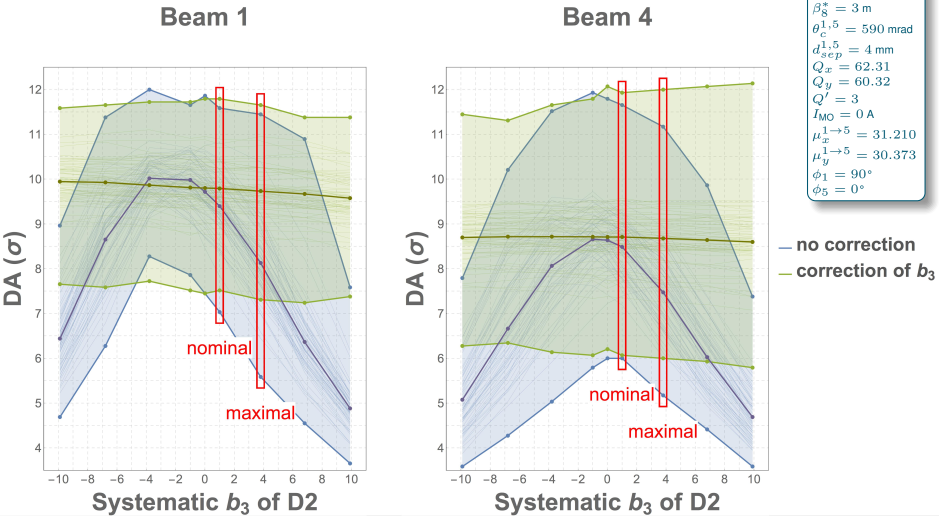
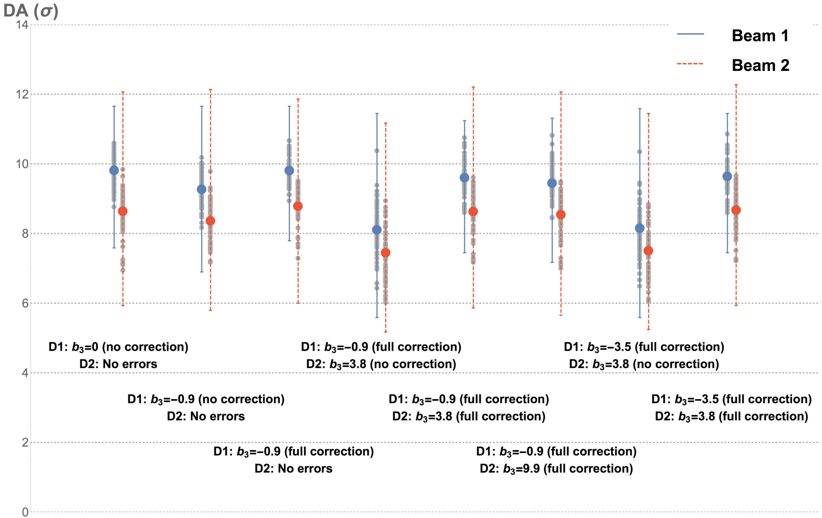


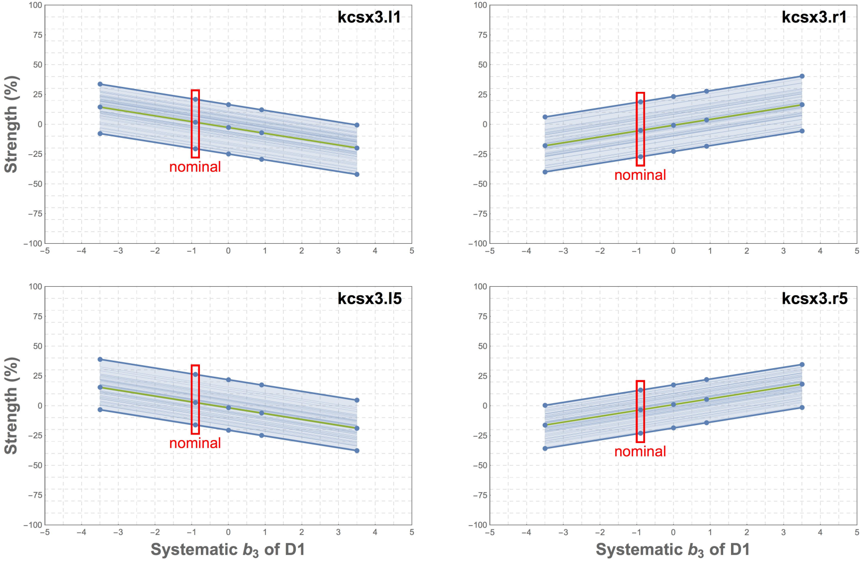
Correction of b_3 of D2

- Correction algorithm for b_3 of D2 works efficiently
- Especially for higher values of b_3

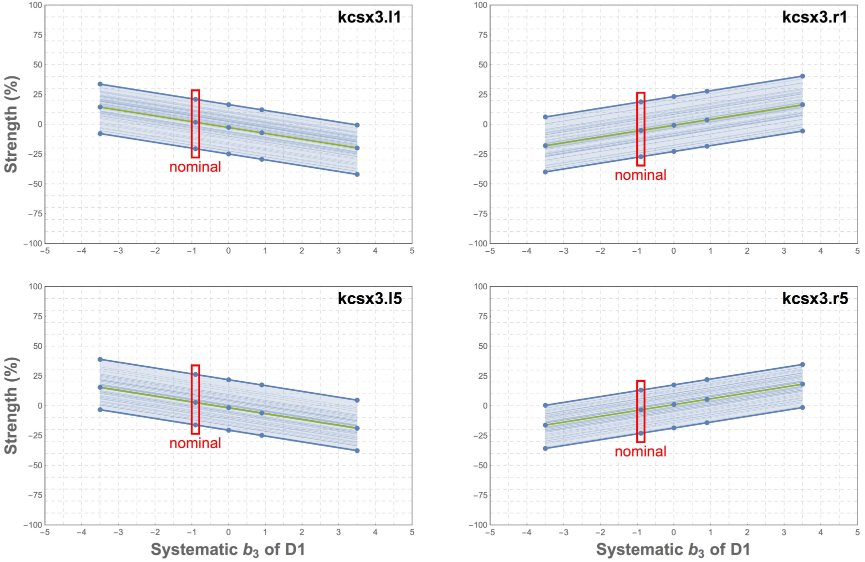
Summary of b_3 correction for D1 and D2



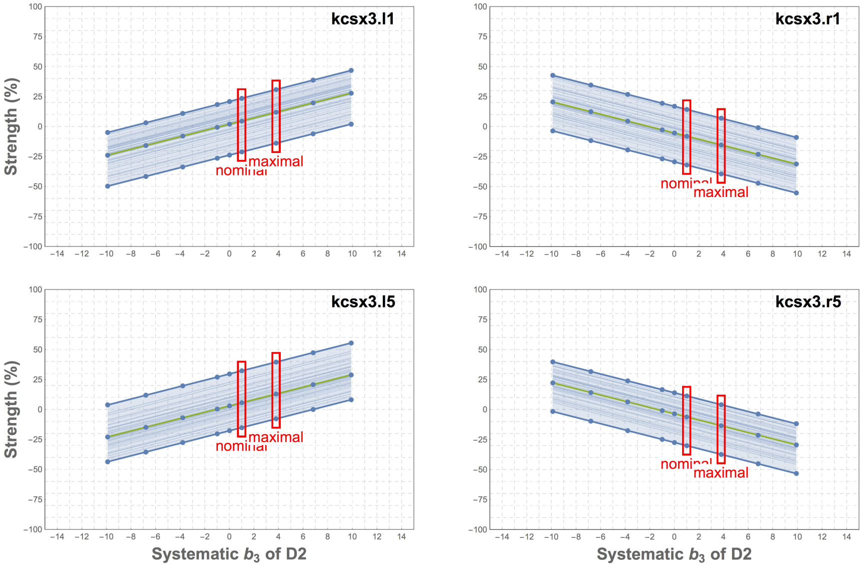
Strength of b_3 correctors for D1 (beam 1)



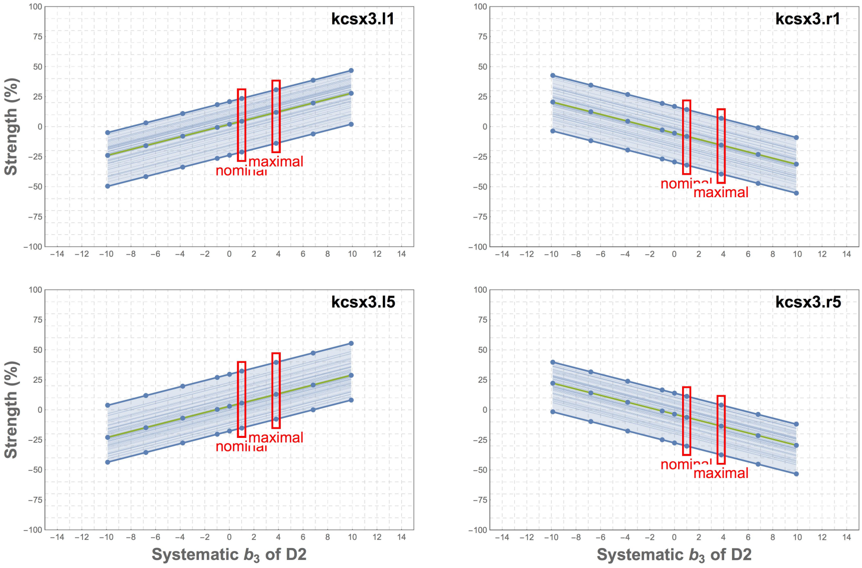
Strength of b_3 correctors for D1 (beam 4)



Strength of b_3 correctors for D2 (beam 1)



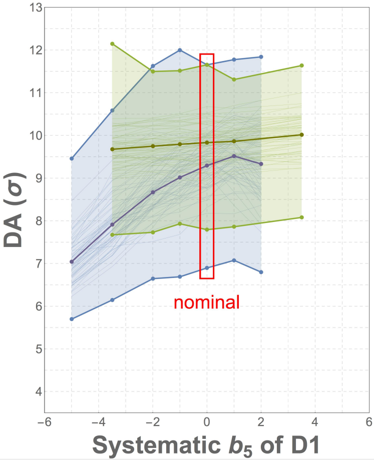
Strength of b_3 correctors for D2 (beam 4)

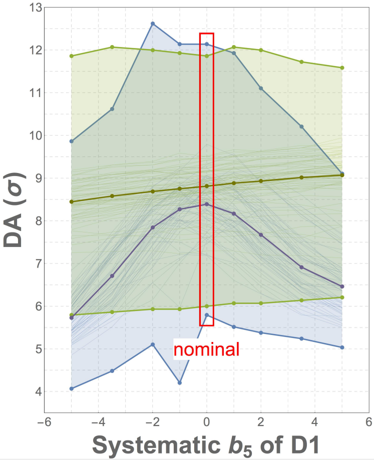


Outline

DA in function of b_5 of D1

Beam 1 (no errors in D2) Beam 4





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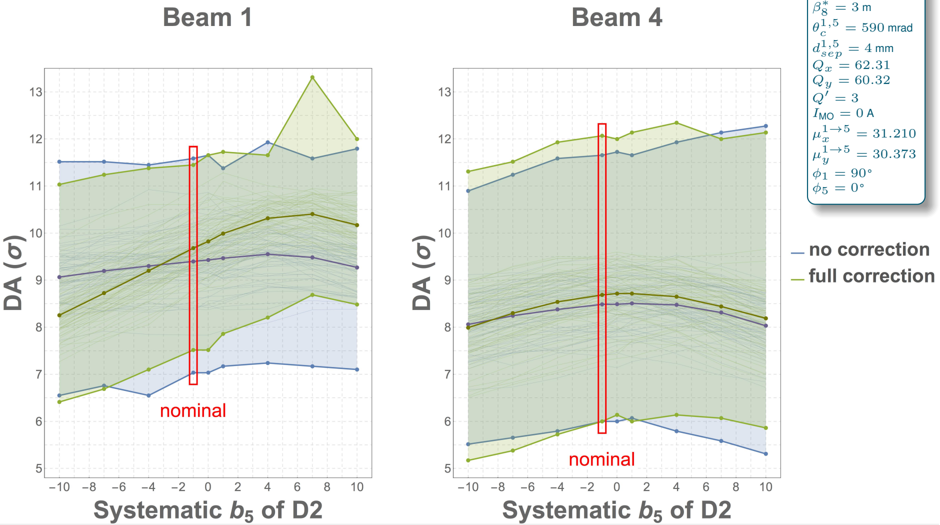
— no correction
— full correction

DA in function of b_5 of D2



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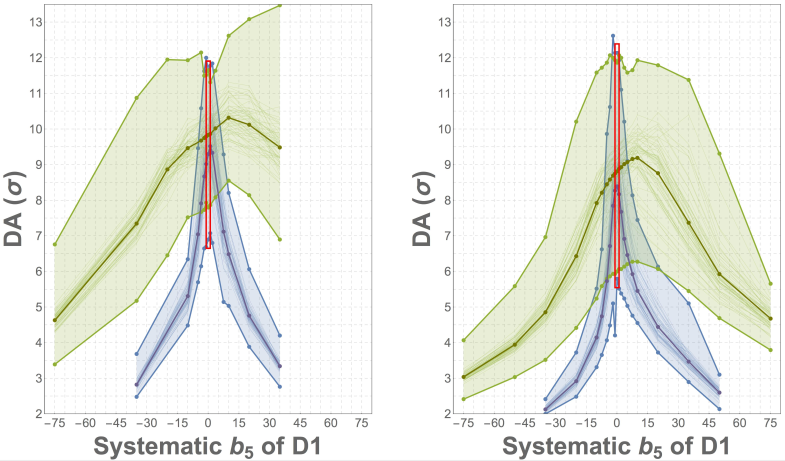
Correction of b_5

- Correction algorithm for b_5 works efficiently in the case of D1 (dependence on b_5 becomes horizontal line)
- But not really for D2 !
- Let's expand the region in b_5 to investigate the trend

DA in function of b_5 of D1

Beam 1 (no errors in D2) **Beam 4**



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— no correction
— full correction

DA in function of b_5 of D2

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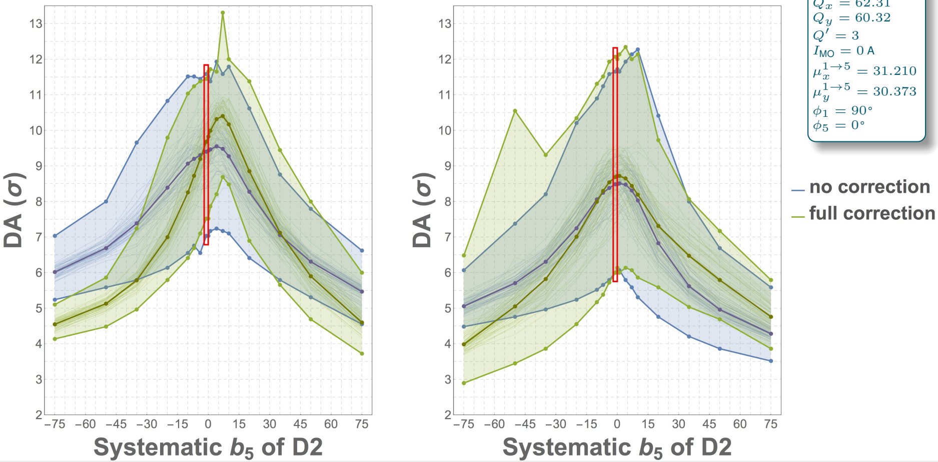
Beam 1 | Beam 4



Correction of b_5

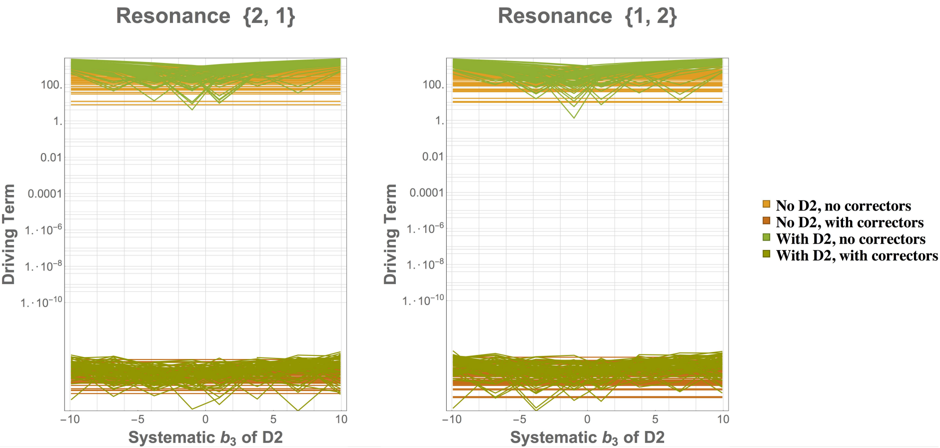
- Correction algorithm for b_5 still works in the case of D1, but less efficient (errors are not fully corrected, but there is still a gain)
- Correction has a minimal effect for the nominal value of b_5 in D2, but lowers dynamic aperture for higher values

  $\Rightarrow$ Correction seems faulty !

- Let's have a look at the resonance driving terms to see if the correction algorithm minimises these

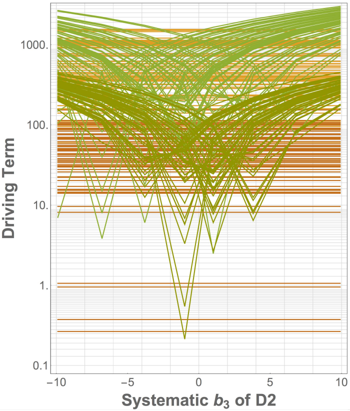
  $\Rightarrow$ Compare b_3 with b_5

Resonance driving terms: b_3 (beam 1)

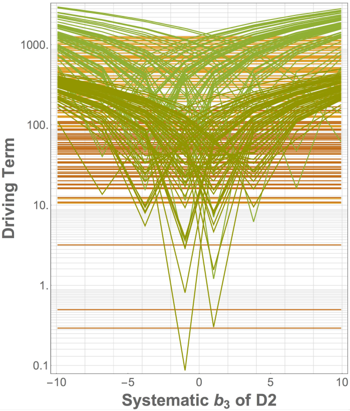


Resonance driving terms: b_3 (beam 1)

Resonance {3, 0}

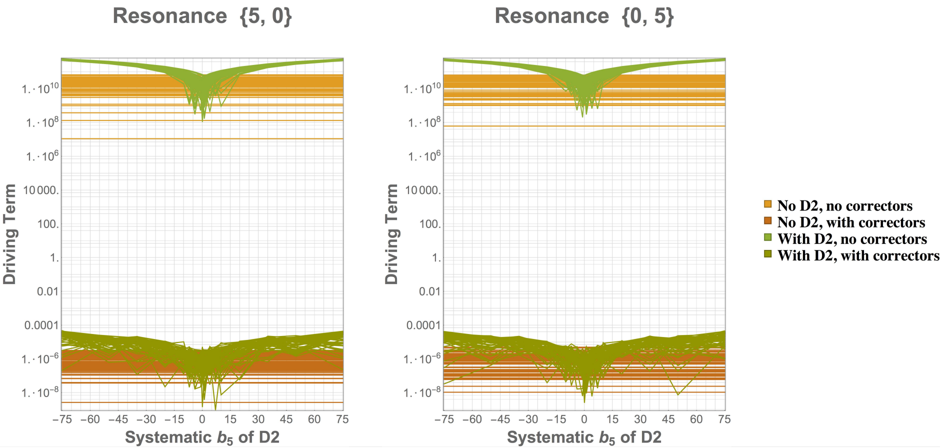


Resonance {0, 3}

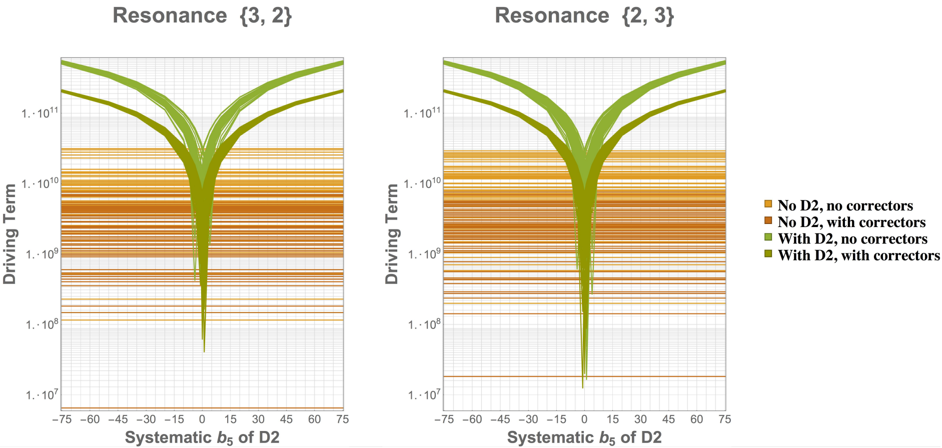


- No D2, no correctors
- No D2, with correctors
- With D2, no correctors
- With D2, with correctors

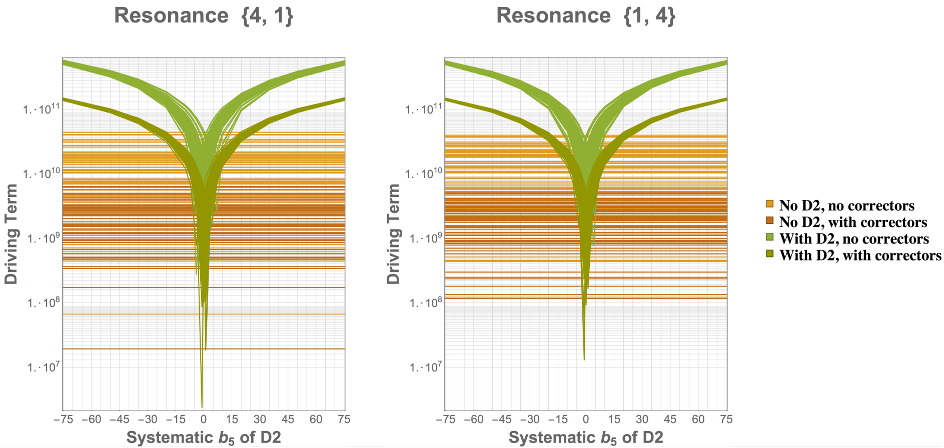
Resonance driving terms: b_5 (beam 1)



Resonance driving terms: b_5 (beam 1)

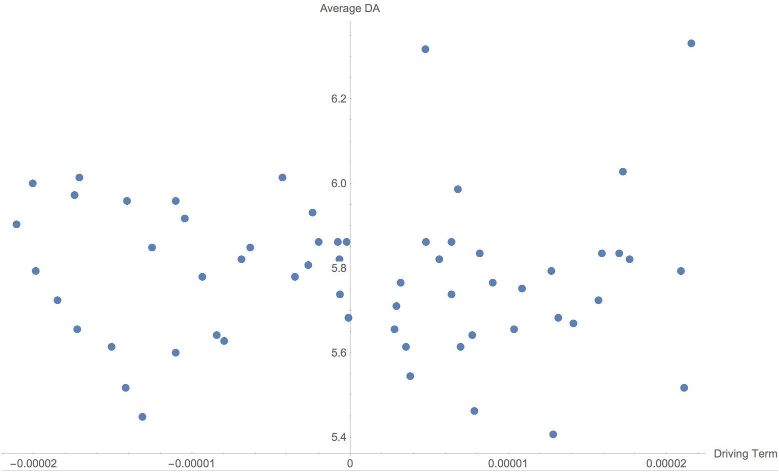


Resonance driving terms: b_5 (beam 1)

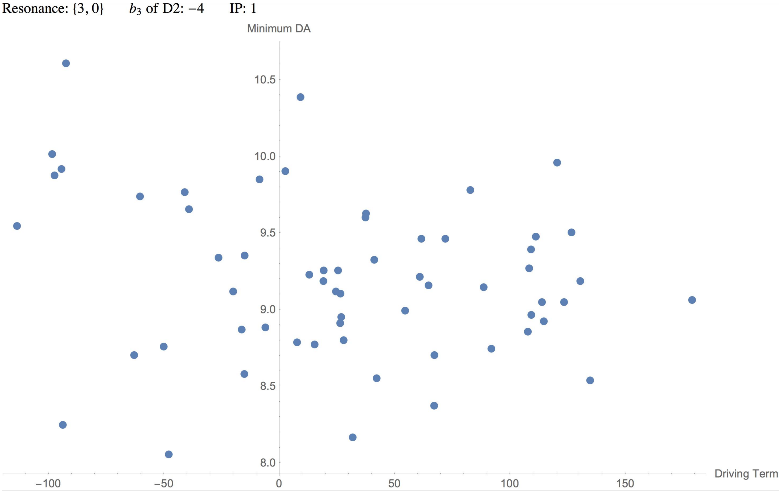


Correlation of Driving Terms and DA

Resonance: {5, 0} b_5 of D2: −35 IP: 1



Correlation of Driving Terms and DA



Conclusion

- There is no difference in the minimisation between b_3 and b_5
- Correlation between driving terms and dynamic aperture is unclear (but should be present)

  $\Rightarrow$ Also not visible for b_3

  $\Rightarrow$ Variation is not big enough
- Need to study the correlation deeper by increasing the random part until the correlation becomes apparent

  $\Rightarrow$ Other resonance might correlate better with DA!

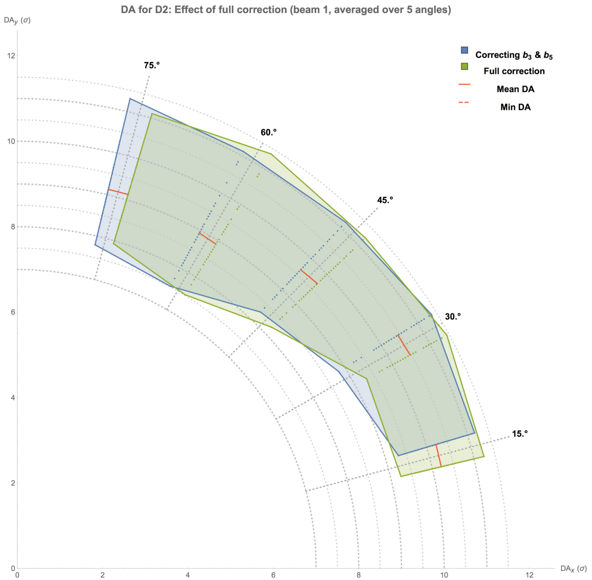
Outline

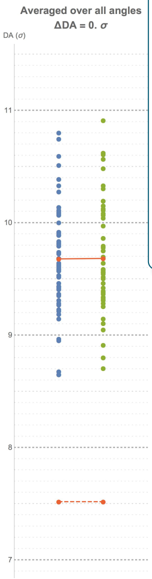
Other orders of D2

- Concerning the systematic part of the errors, only b_3 and b_5 can be corrected
- But for the random parts, all orders can be corrected (still by taking the average over both beams)
- This might be overly optimistic and no reproducable in reality

  $\Rightarrow$ However, effect is expected to be neglicible

  $\Rightarrow$ Investigate the impact on DA of correcting other orders





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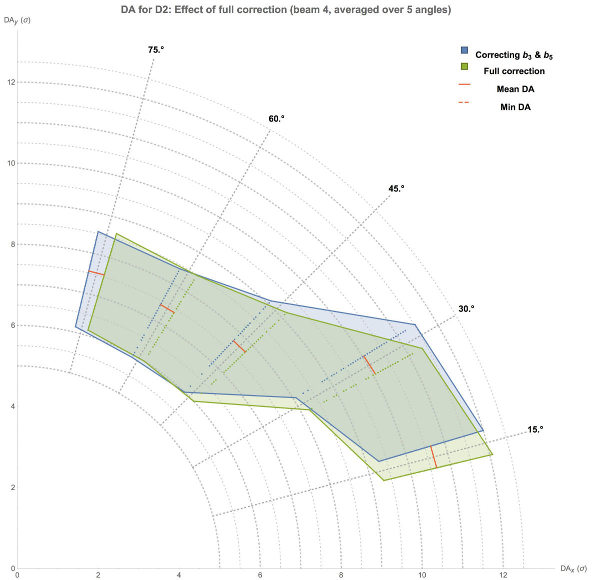

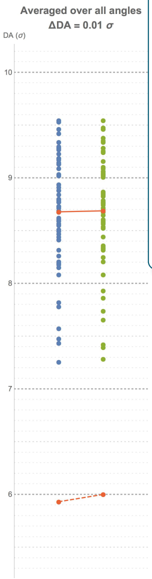

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Final Conclusions

- Correction of b_3 works very well
- Correction of b_5 is a bit less reliable; maybe other choice of resonance minimisation improves the situation
- Correction of other orders has no effect (as expected)